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ties. Hence, if we take the azotic atmosphere as a standard, the oxygenous and the carbonic acid will observe a decreasing ratio to it in ascending, and the aqueous vapour an increasing one. The specific gravity of oxygenous and azotic gases being as 7 to 6 nearly, their diminution in density will be the same at heights reciprocally as their specific gravities. Hence it would be found, that at the height of Mount Blanc (nearly three English miles), the ratio of oxygenous gas to azotic, in a given volume of air, would be nearly as 20 to 80:—consequently it follows that at any ordinary heights the difference in the proportions will be scarcely if at all perceptible*.

LXVII. *Experiments on the Torpedo, by Messrs.* HUMBOLDT *and* GAY-LUSSAC. *Extracted from a Letter from M.* HUMBOLDT *to M.* BERTHOLLET, *dated Rome, 15 Fructid. Year* 13†.

THE phænomena of electric fish ought to be the subject of our renewed researches, with a view to the opinion of many philosophers, who conceive that they are capable of being explained upon the principles of that beautiful theory with which Volta has enriched science. You well know, my respected friend, what must have been our anxiety to procure the torpedo; and you will perhaps be astonished that I should be so long in writing to you respecting it. At Genoa we found some of them, but we were then without instruments. At Civita Vecchia we searched for them in vain. At last, during our stay at Naples, we procured them very frequently, of great size, and very vigorous. I shall relate to you, in this letter, the series of experiments which M. Gay-Lussac and I have instituted upon the action of the torpedo (Raja Torpedo of Linnæus). M. de Buch, a German mineralogist, was present at our experiments. I present to you the results which they afforded, and relate the facts without introducing any theoretical notions.

Our experiments were principally intended to discover those conditions in which the torpedo is unable to commu-

* Air brought from the summit of Helvelyn, in Cumberland (1100 yards above the sea—barometer being 26,60), in July 1804, gave no perceptible difference from the air taken in Manchester. M. Gay-Lussac determines the constitution of air brought from an elevation of four miles to be the same as that at the earth's surface.

† From *Annales de Chimie*, no. 166.

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nicate those shocks termed electric, although the feeling is very different from that which is occasioned by the discharge of a Leyden phial. Having at hand no other work besides that of Aldini, in which he has combined into one view the beautiful researches of Geoffroy with those of Spallanzani and Galvani, we shall not have it in our power to compare our own labours with those of preceding philosophers.

1. Although the power of the torpedo cannot be compared to that of the gymnotus, it is not less capable of occasioning disagreeable sensations. A person much in the custom of receiving electric shocks, supports with some difficulty the shock of a torpedo 14 inches long, and in a state of perfect vigour. The gymnotus communicates its influence under water, unless when much weakened.

M. Gay-Lussac has observed, that the action of the torpedo in this condition is not perceptible until it is raised above the surface of the water. It is with this fish, as with frogs on which Galvanic experiments are made: the circumstances under which the contraction takes place, vary according to the degree of excitability in the organs.

2. I have remarked, while in South America, that the gymnotus gives the most frightful shocks without making any external motion of the eyes, head, or fins: it moves no more than one person communicating an idea or sensation to another. But the torpedo, on the contrary, moves its pectoral fins in a convulsive manner before each shock; and the violence of the stroke is always proportioned to the extent of the surface of contact.

3. The organs of the torpedo, or gymnotus, cannot be discharged by us at will, like a Leyden phial or a Galvanic pile; nor does the electric fish uniformly communicate a shock when touched. It must be irritated that it may give its stroke; for this action depends upon the will of the animal, which in all probability does not always keep its electric organs charged: it charges them, however, with astonishing celerity, and is thus able to give a long series of shocks.

4. The shock is felt, provided the animal is disposed to give it, when a single finger is applied to a single surface of the electric organs; or when the two hands are placed one on the upper and the other on its under surface at the same time. And in either of these cases the shock is equally communicated, whether the person be insulated or not.

5. If a person while insulated touches the torpedo with his finger, it is indispensably necessary that the finger be in

immediate contact; for no shock is communicated when a conducting body, such as a piece of metal, is interposed between the finger and the organs of the fish. Thus we may touch the animal with a key, or other metallic instrument, and experience no shock in consequence.

6. M. Gay-Lussac having observed this important fact, we placed the torpedo on a plate of metal, so that the inferior surface of its electric organs was in contact with the metal. The hand which supported the plate felt no shock, although another person in a state of insulation irritated the animal, and when the convulsive motions of its pectoral fins plainly indicated very powerful discharges of its electric fluid.

7. If on the contrary a person support the torpedo placed on a metallic plate, with his left hand as in the preceding experiment, and with his right touches the upper surface of the electric organ, then a violent shock is felt in both arms at the same moment.

8. The same feeling is experienced when the fish is placed between two plates of metal, the edges of which do not touch, and the person applies a hand to each plate at the same instant.

9. But if in the preceding experiment there exists an immediate communication between the edges of the two plates, no shock is felt in the arms; for in this case the chain of connection between the two surfaces of the organ is formed by the plates, and the new communication established by applying the two hands to the plates becomes altogether inefficient.

10. The most delicate electrometer does not indicate the state of electricity of the organs of the torpedo: it is no way affected by any method which we can have recourse to, either by bringing it near to the organs, or by insulating the fish, covering it with a plate of metal, and then forming a communication by means of a wire between the plate and the condenser of Volta. Nothing shows here, as in the gymnotus, that the animal can modify the state of electricity of surrounding bodies.

11. As electric fish act while in a state of health with the same power under water as in the air, we examined the conducting properties of this fluid. A number of persons having formed a circle of connection between the upper and under surfaces of the organs of the torpedo, no shock was experienced till they had moistened their hands with water. The shock is equally felt when two persons who have their right hands applied to the torpedo, instead of taking hold of

 each

each other's left hands, plunge a pointed piece of metal into a drop of water placed upon an insulating body.

12. By substituting flame instead of a drop of water, the communication is interrupted, and no sensation is experienced until the two pieces of metal touch each other within the flame.

13. We must also observe that no shock will take place either in air or under water, unless we immediately touch the body of the electric fish. They are unable to give their stroke through a layer of water, however thin; a fact which is the more remarkable, as we know that in Galvanic experiments, where the frog is placed under water, it is sufficient to bring the silver forceps near to the muscles, and that the contraction takes place when the layer of water interposed is one or two millimetres in thickness.

Such, my respected friend, are the principal observations which we have made upon the torpedo. Experiments 4th and 10th prove that the electric organs of these animals manifest no tension or excess of charge. We should rather be inclined to compare their action to a chain of small Leyden phials than to the pile of Volta. As some communication is always necessary for the occurrence of a shock, and having received strokes from the gymnotus through very dry cords, I conclude that in the case where this powerful animal appeared to give these violent shocks without the existence of any communication, it must have arisen from my imperfect insulation. If the torpedo acts by poles, by an electrical equilibrium which tends to re-establish itself, experiments 5th and 6th seem to prove that these poles exist near one another upon the same surface of the organ: for we feel the shock by touching a single surface with the finger. A plate interposed between the hand and the organ (6.) re-establishes of itself the equilibrium, and the hand which supports this plate feels nothing, because it is out of the current of the electric influence. But if we suppose a number of poles of different descriptions upon each surface of the organ, why is it that, by covering these with two metallic plates the edges of which do not touch, and placing the hands upon these plates, the equilibrium is re-established through the medium of the arms? Wherefore, it may be asked, does not the positive electricity of the inferior surface seek, at the moment of explosion, the negative electricity of the neighbouring pole? and wherefore does it find it only in the superior surface of the electric organ? These difficulties are perhaps not in-

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sumountable, but the theory of these *vital actions* requires still further research. Geoffroy* has proved that rays, which do not exhibit any marks of electricity, possess organs very analogous to those of the torpedo. The least injury of the brain of this animal prevents its electrical action. The nerves, therefore, without doubt, act the chief part in the production of these phænomena; and the physiologist, who takes a general and enlarged view of the vital actions, would with reason oppose the ideas of the philosopher, who conceives he can explain the whole by the contact of the albumino-gelatinous pulp with the tendinous septa which nature has combined in the formation of the organs of the torpedo.

LXVIII. *Notices respecting New Books.*

The Philosophical Transactions of the Royal Society of London for 1805, Part II., contain the following papers: 1. Abstract of Observations on a Diurnal Variation of the Barometer between the Tropics. By J. Horsburgh, Esq.—2. Concerning the Difference in the Magnetic Needle, on board the Investigator, arising from an Alteration in the Direction of the Ship's Head. By Matthew Flinders, Esq. Commander of His Majesty's Ship Investigator.—3. The Physiology of the Stapes, one of the Bones of the Organ of Hearing; deduced from a comparative View of its Structure and Uses in different Animals. By Anthony Carlisle, Esq. F. R. S.—4. On an Artificial Substance which possesses the principal characteristic Properties of Tannin. By Charles Hatchett, Esq. F. R. S.—5. The Case of a full grown Woman in whom the Ovaria were deficient. By Mr. Charles Pears, F. L. S.—6. A Description of Malformation in the Heart of an Infant. By Mr. Hugh Chudleigh Standart.—7. On a Method of analysing Stones containing fixed Alkali, by means of the Boracic Acid. By Humphrey Davy, Esq. F. R. S.—8. On the Direction and Velocity of the Motion of the Sun and Solar System. By William Herschel, LL.D. F. R. S.—9. On the Reproduction of Buds. By Thomas Andrew Knight, Esq. F. R. S.—10. Some Account of Two Mummies of the Egyptian Ibis, one of which was in a remarkably perfect State.

* For M. Geoffroy's paper, see Phil. Mag. vol. xv. p. 126.